

PUPILS' OUTLINES FOR HOME STUDY

IN CONNECTION WITH SCHOOL WORK

PHYSICS, PART I

Properties of Matter — Mechanics,
Pendulum, Hydrostatics, Pneumatics

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Physics is that branch of Science which treats of matter and the laws governing the many physical phenomena accompanying it in its various states.

PROPERTIES OF MATTER.

Matter is anything which occupies space: as iron, wood, water, air.

Three Forms of Matter.

1. **Solid**—A body which under ordinary conditions does not change its shape,

EXPERIMENT—Place a piece of steel on a table, try to change its shape by pressing it with the hands, try to take up only a small part of it. *Result*—Its shape remains the same, all parts being held together.

2. **Liquid**—A body which under ordinary conditions may change its shape to suit the vessel containing it but which keeps a level surface and a definite volume.

EXPERIMENT—Pour water into a glass then pour it into a pan. *Result*—It took the shape of the vessel holding it and was level on top.

3. **Gas**—A body which under ordinary conditions has the tendency to expand and fill any given place, conforming in shape and volume to the space containing the gas.

EXPERIMENT—Place a bottle which seems to be empty under an air pump and we find we can remove air from it, causing a vacuum which is instantly filled on being exposed to the air.

EXPERIMENT—Open a gas jet, permitting the gas to escape. *Result*—In a very short time the odor of gas may be detected in all parts of the room.

Atoms are the smallest particles of matter that exist.

Molecules are the particles of which matter is composed and consist of one or more atoms.

Volume is the amount of space a body fills.

Energy is the power of producing a change of any kind.

Physical Change is one where the molecules remain the same.

EXPERIMENT—Break a stick of wood into small pieces. *Result*—No matter how small the pieces they are still wood.

EXPERIMENT—Dissolve salt in water, then evaporate the water and the salt remains.

Chemical Change is one where the molecules are destroyed and new ones take the place of the old.

EXPERIMENT—Take a stick of wood and set fire to it. *Result*—Instead of wood remaining we have a new substance—ashes.

Impenetrability is that property of matter by which no two bodies can occupy the same space at the same time.

EXPERIMENT—Place a book on the table and we find we cannot at the same time place a glass in the same place.

Hardness is a property of matter which causes difficulty in penetrating between its particles; but nothing is absolutely hard or soft, as these are only terms of comparison; as wood is harder than wax but softer than steel.

EXPERIMENT—Try to scratch with a nail a piece of wax, wood, steel, glass, and observe the different effect on each.

Crystallization. Some solids in solution show the formation of definite geometrical shapes or crystals. When this occurs there is an increase in volume as shown by the bursting of water pipes when water freezes.

Cohesion is that property by which the molecules of like substances are held together.

Adhesion is that property by which the molecules of different substances are held together: as glue holding boards together.

Ductibility is that property by which matter can be drawn to a wire or rod. Platinum may be drawn into a very fine wire; glass may also be drawn to a thread; wood cannot be drawn into a wire.

Malleability is that property by which matter can be hammered or rolled into sheets. Brass may be rolled into very thin sheets, but tin foil, gold and silver leaf are the best examples of malleability.

Elasticity is that property by which a body returns to its original form when the force which caused the change has been removed. Elasticity may be caused by pressure, pulling, bending, or twisting.

EXPERIMENTS—

1. Press a rubber ball between the fingers and it regains its shape as soon as the pressure is removed.

2. A small rubber band can be stretched over a book so as to hold it close, but will return to its original size when removed.

3. Take a stick of rubber used for erasing and bend the two ends over until they meet. Upon releasing the ends the eraser assumes its original shape and position.

4. Twist a piece of rubber tubing and upon releasing it, it returns to its original shape.

This is the principle upon which springs are made.

Porosity is that property of having pores or spaces between the particles of matter. These pores vary in size from those of a sponge, distinctly visible, to those in a metal which are invisible even with a microscope.

EXPERIMENT—Fill a tube with peas then drop in shot, then pour in chalk dust, and finally we will find there is even room for water, though the tube was apparently full in the first instance.

Compressibility is that property by which matter may be reduced in size by pressure.

EXPERIMENT—Drive a nail into a piece of pine wood. Split it open and remove the nail and we find the wood has been pressed back, forming a circular hole for the nail.

Expansibility is that property by which matter may be increased in size.

EXPERIMENT—Press down the piston of a bicycle pump and leave it a short time and we find the air under it has expanded requiring more room and so has raised the piston.

Divisibility is that property by which matter may be separated into parts.

EXPERIMENT—Take a tumbler full of water and though full we may drop in considerable fine table salt and it will not be visible having separated the particles of water and become part of it.

Indestructibility is that property which prevents matter from being destroyed. It may take a different form by chemical change, may become different matter, but it cannot be lost or destroyed.

Tenacity is that property by which the particles of matter tend to hold together.

EXPERIMENT—Take a piece of iron wire and by pulling and bending and twisting try to separate into different pieces. *Result*—It could not be broken or separated except with difficulty.

Brittleness is the property by which particles readily separate under pressure and so the body is easily broken, as glass.

Diffusibility is that property of a liquid by which in mixing it with another liquid it will be evenly distributed throughout.

EXPERIMENT—Pour a few drops of red ink into a little water and after mixing it we find the whole solution has a reddish tinge.

Capillarity is that property by which liquids may be absorbed or drawn into a solid because of its porosity.

EXPERIMENT—Dip only the end of a towel in a basin of water, and soon the whole towel is wet due to the capillary attraction.

Another example is the absorbing of ink by blotting paper.

Motion is a change of position.

Inertia is the tendency of a body to remain still if at rest or to continue in motion if moving.

Force is that which tends to either move a body or to stop a body from moving.

Measurements are reckoned from definite accepted units: as

1. **Spaces of One Dimension** are lengths measured from the unit YARD of 36 inches, or from the METER of 39.37 inches.
2. **Spaces of Two Dimensions** are surfaces measured from a unit which is the

square of whatever unit has been used in the length. The AREA is usually given either in ACRES or ARCS.

3. **Spaces of Three Dimensions** are solids measured from a unit of volume, which is the product of the length, breadth and thickness or the cube of whatever unit has been used in the length. Volume or solidity is usually given in CUBIC FEET, CUBIC METERS or CUBIC CENTIMETERS.
4. **Time** is usually measured from the unit, SECOND or HOUR.
5. **Mass** is measured by a balance and the unit is the POUND or KILOGRAM (about two and one-fifth pounds).
6. **Capacity** is measured by the unit QUART or LITER. A liter is the same as a cubic decimeter and weighs one kilogram.

MEASUREMENTS.

m. = milli, c. = centi, d. = deci, D. = deka, H. = hekto, K. = kilo, m. = myria.

MEASURE OF LENGTH.

The unit is meter.

12 inches = 1 foot.	10 millimeters = 1 centimeter = .3937079 inches.
3 feet = 1 yard.	10 centimeters = 1 decimeter = 3.937079 inches.
5½ feet = 1 rod.	10 decimeters = 1 meter = 39.37079 inches.
5280 feet = 1 mile.	10 meters = 1 Dekameter = 393.7079.
	10 Dekameters = 1 Kektometer = 3937.079.
	10 Hektometers = 1 Kilometer = 3280.9 feet.
	10 Kilometers = 1 Myriameter = 32809 feet.

MEASURE OF SURFACE.

The unit is meter.

144 sq. inches = 1 sq. foot.	100 sq. mm. = 1 sq. cm. = .155 sq. in.
9 sq. feet = 1 sq. yard.	100 sq. cm. = 1 sq. dm. = 15.5 sq. in.
30¼ sq. yards = 1 sq. rod.	100 sq. dm. = 1 sq. m. = 10.764 sq. feet.
160 sq. rods = 1 acre.	100 sq. m. = 1 sq. Dm. = 119.6 sq. yards.
640 sq. acres = 1 sq. mile.	100 sq. Dm. = 1 sq. Hm. = 395.371 sq. rods.
	100 sq. Hm. = 1 sq. Km. = 247.10 acres.
	100 sq. Km. = 1 sq. Mm.

sq. m. is called a centare; sq. Dm. = arc; sq. Hm. = hektare.

MEASURE OF SOLIDS.

The unit is meter.

1728 cu. inches = 1 cu. foot.	1000 cu. mm. = 1 cu. cm. = .06102 cu. inches.
27 cu. feet = 1 cu. yard.	1000 cu. cm. = 1 cu. dm.
	1000 cu. dm. = 1 cu. m. = 35.314 cu. feet.

Cubic m. = stere.

MEASURES OF CAPACITY.**Liquid Measure.**

The unit is liter.

4 gills = 1 pint.
 2 pints = 1 quart.
 4 quarts = 1 gallon.
 1 gallon = 231 cubic inches.

10 ml. = 1 cl. = .6102 cu. inches.
 10 cl. = 1 dl. = 6.102 cu. inches.
 10 dl. = 1 liter = 1.0567 liquid quarts.
 10 l. = 1 Dl. = 10.567 l. q.
 10 Dl. = 1 Hl. = 26.417 gallons.
 10 Hl. = 1 Kl. = 264.17 gallons.

Dry Measure.

The unit is liter.

2 pints = 1 quart.
 8 quarts = 1 peck.
 4 pecks = 1 bushel.
 1 bushel = 2150.42 cubic inches.

10 dl. = 1 l. = .908 dry quarts.
 10 l. = 1 Dl. = 9.08 dry quarts.
 10 Dl. = 1 Hl. = 2.8375 bushels.

MEASURE OF WEIGHT.

The unit is gram.

16 ounces = 1 pound.
 2000 pounds = 1 ton (short).
 2240 pounds = 1 long ton.

10 mgram. = 1 cg. = .15432 grains.
 10 cg. = 1 dg. = 1.5432 grains.
 10 dg. = 1 gram.
 10 g. = 1 Dg.
 10 Dg. = 1 Hg.
 10 Hg. = 1 Kg. = 2.20462 lbs.
 10 Kg. = 1 Mg.
 10 Mg. = 1 Quintal.
 10 Q. = 1 Metric Ton = 2204.621 lbs.

gram = 1 cubic centimeter.

kilogram = 1 cubic decimeter.

metric ton = 1 cubic m. distilled water at greatest density.

EQUIVALENTS.

1 inch = 2.54 cm.
 1 foot = 30.48 cm.
 1 yard = 0.9144 m.
 1 mile = 1.6093 Km.
 1 sq. inch = 6.452 sq. cm.
 1 sq. foot = 9.2903 sq. dm.
 1 sq. yard = .8361 sq. m.
 1 acre = .4047 Ha.
 1 sq. mile = 2.59 sq. Km.

1 cubic foot = 28.317 cubic dm.
 1 cubic yard = .7645 cubic m.
 1 liquid quart = .9463 liter.
 1 gallon = 3.785 liter.
 1 dry quart = 1.101 liter.
 1 bushel = .3524 Hl.
 1 grain = .0648 gram.
 1 ton (short) = .9072 M. T.
 1 troy oz. = 31.1035 gram.
 1 av. oz. = 28.35 gram.
 1 av. pound = .4536 Kg.

1 m. = 39.37 inches.
 1 km. = $\frac{5}{8}$ mi.
 1 cu. dm. = 1 liter.

1 liter = 1 quart.
 1 liter = 1 kg.
 1 kg. = $2\frac{1}{2}$ lbs.

GRAVITY OR GRAVITATION.

Gravity is the force which draws bodies toward the centre of the earth.

Weight of a body is the measurement of gravity and is shown by the downward pressure.

EXPERIMENT—Place a book on the hand and it feels heavy. Gravity is tending to pull it toward the center of the earth, but the hand prevents this and so receives the pressure known as *weight*.

Center of Gravity of a body or the CENTER OF MASS is the single point at which an upward force may be applied and the body remain at rest in whatever position it is placed.

EXPERIMENT (1)—By means of a tack suspend an irregular sheet of paper on the wall, fastening the plumb line to the tack so that it will fall over the paper. With a pencil mark a line indicating the position of the plumb line. Suspend the paper from various points tracing the direction of the plumb line each time. *Result*—All lines crossed at a common point, the *center of gravity* of the paper.

EXPERIMENT (2)—Balance a sheet of paper on the end of a pencil, until the point is found where it remains at rest. *Result*—The paper was balanced only at one point, the *center of gravity*.

The Line of Direction is the line passing from the center of gravity toward the center of the earth.

LAWS OF GRAVITATION.

1. The speed with which a body falls is independent of its mass.

EXPERIMENT—Into a tube place a cent and a small piece of feather. Exhaust the air in the tube, forming a vacuum, and invert it. We find both bodies fall and reach the bottom at the same time. If this experiment is tried without creating the vacuum, we find a difference in speed owing to the resistance offered by the air.

2. The intensity of the earth's attraction varies as the mass, so if the mass of one body is three times that of another it requires three times the force to give it the same speed.

Bodies are lighter the higher above the earth they are raised. Galileo proved the above laws by the experiments he performed from the Leaning Tower of Pisa, Italy.

EQUILIBRIUM.

A body is in *equilibrium* if when in a state of rest, it is perfectly balanced.

1. **Stable Equilibrium**—If a body displaced tends to return to its original position it is in *stable equilibrium*. When displaced the tendency is to raise the center of gravity and if the line of direction falls within the base the body stands.

EXPERIMENT—Place a cone on its base, displace it by slightly tipping it, so that at no time the line of direction extends beyond the base. *Result*—The cone rights itself, returning to the original position on its base.

A Stable Body should have a *broad base* and the *center of gravity low* as in a pyramid. Thus a wagon load of stone will be more stable than a wagon load of hay weighing the same for the center of gravity is lower in the first.

2. **Unstable Equilibrium**—If a body displaced tends to move farther from its original position it is in *unstable equilibrium*. When displaced the tendency is to lower the center of gravity. If the line of direction falls beyond the base of the body it will fall.

EXPERIMENT—Place a ruler vertically on one of the small ends, and slightly displace it. *Result*—The ruler falls as soon as the line of direction falls beyond the base.

N. B.—In the two above experiments we find that the cone has a broad base and the center of gravity is low and hence is more stable than the ruler which has a small base and the center of gravity high.

3. **Neutral Equilibrium**—If a body displaced tends neither to return to its original position nor to move farther from it, it is in *neutral equilibrium*. When displaced the tendency is to neither raise nor lower the center of gravity.

EXPERIMENT—Slightly displace a ball. *Result*—The ball rolls a short distance and stops, there being no tendency to return to its original position, or to continue in motion, and as the center is equidistant from all parts of a sphere we find that the center of gravity has neither been raised nor lowered.

PARALLELOGRAM OF FORCES.

If two forces meet at right angles to each other the resultant force will be in a diagonal direction from the apex of the angle.

COMPOSITION OF FORCES.

If there are more than two forces find the resultant of any two, then take that answer and find the resultant of it and a third force and so on till all forces have been considered.

(Resultant is motion produced by the combination of two or more forces acting together.)

PENDULUM.

A Pendulum is a weight suspended so that it can swing freely.

The motion of a pendulum is caused by *gravity* and *inertia*. In setting it in motion the pendulum is pulled to one side and then released, the force of gravity drawing it down to the lowest point but having once been set in motion its tendency is to continue in that state so it is drawn upward, when the force of gravity is again exerted.

Vibration—One swing of the pendulum to and fro.

LAWS OF THE PENDULUM.

1. **The Material** of which a pendulum is made causes no difference in the number of vibrations.

EXPERIMENT—Suspend and swing, starting all at the same time, three pendulums of equal length with weights made of lead, brass, wood. *Result*—By counting we find the number of vibrations made in a given time by each pendulum to be the same as the others.

2. **The Weight** of the pendulum causes no difference in the number of vibrations.

EXPERIMENT—Suspend and swing two pendulums of equal length, one with a small wooden weight and the other with a larger leaden weight. *Result*—The number of vibrations in a given time is the same for both.

3. **The Size of the Arc** through which the pendulum vibrates causes no difference in the number of vibrations.

EXPERIMENT—Suspend and swing pendulums, starting both at the same time, two pendulum weights of the same size and material, and strings of equal length, but draw one further out than the other and count the vibration. *Result*—There will be the same number of vibrations in a given time for both.

4. **The Shorter** the pendulum the **Greater** the number of vibrations in a given time.

EXPERIMENT—Suspend and swing two pendulums with weights of the same size and material but with one string shorter than the other, starting both at the same time and count the vibrations. *Result*—The pendulum with the shorter string makes more vibrations in a given time than the other.

Uses—The main use for the pendulum is as a time piece. The vibration regulates the motion of the hands. Each vibration permitting one tooth of the cog wheel to escape, so if the wheel has ten teeth it will rotate once while the pendulum swings to and fro ten times. The length of the pendulum varies with the changes of temperature, so in order to correct this the weight or bob may be raised or lowered on the wire support.

MECHANICAL POWERS.

1. **A Machine** is a device for doing work which could not be performed by our own power.
2. There are *six simple machines* or mechanical powers; the *lever, pulley, wheel and axle, inclined plane, wedge, screw*. The classification is sometimes given, as the lever with its modifications, the pulley and wheel and axle; the inclined plane with its modifications, the wedge and screw.
3. **Rule for all Machines.** The product of the power and the power distance is equal to the product of the weight and the weight distance.

EXPERIMENT—Suspend a yard stick by its middle point having inserted five hooks on each side of the middle, three inches apart. Hang four small weights from each of the two hooks eight inches from the fulcrum or the balancing point. Remove two weights from one side and move the four weights on the other side, to the hook four inches from the center. Then remove so that one weight remains at eight inches from the center on one side and the four weights on the other side move to the hook two inches from the center. **Result**—In each case the weights on one side balanced those on the other, and we found that the product of the

$$\text{Weight } 4 \times \text{Weight Distance } 8 = \text{Power } 4 \times \text{Power Distance } 8 \quad (32)$$

$$\text{" } 2 \times \text{" } 8 = \text{" } 4 \times \text{" } 4 \quad (16)$$

$$\text{" } 1 \times \text{" } 8 = \text{" } 4 \times \text{" } 2 \quad (8)$$

LEVERS.

A Lever is a rod of any kind that will move on a pivot or rest.

The Fulcrum is the point on which the lever moves.

The Power is the force applied to one part of the lever in order to move the body.

The Weight is the body to be moved by the application of the power.

The Power Arm or **Power Distance** is the space between the fulcrum and the power.

The Weight Arm or **Weight Distance** is the distance from the fulcrum to the weight.

Lever are divided into THREE classes:

1. **A Lever of the First Class.**

This lever has the fulcrum placed between the power and weight; as in a *crow-bar, scales, scissors, seesaw, steelyard, hammer* used to draw out a nail, *pincers*. It may be of great or less advantage to use this lever according as the power arm is greater or less than the weight arm.

2. **A Lever of the Second Class.**

This lever has the weight placed between the power and the fulcrum; as a *nut-cracker, lemon squeezer, wheelbarrow, opening a door, oar* when rowing, *bridges* and *girders*. The use of this lever is always of great advantage.

3. A Lever of the Third Class.

This lever has the power placed between the weights and the fulcrum, as in the sugar or candy *tongs*, *sheep shears*, *forearm* when lifting weights. The advantage of using this lever is less, for the force is being used to gain speed as well as to accomplish the work.

Rule—The product of the power and power distance is equal to the product of the weight and the weight distance.

PULLEYS.

A Pulley is a wheel having a grooved rim for carrying a rope. It turns on an axis and is fastened in a frame called a **PULLEY BLOCK**.

There are two kinds of pulleys:

1. Fixed Pulley.

This form of pulley is a modified lever of the First Class. The power arm is equal to the weight arm but there must be as much or more power than weight in order to overcome friction, hence there is no mechanical advantage in using a fixed pulley except for obtaining a change of direction.

EXPERIMENT—Suspend a pulley placing a string over the pulley with equal weights attached at each end. The two weights balance each other. Move one, called the power, downward; and the other moves upward. The fulcrum is the axle of the pulley. **Result**—The distance from the fulcrum to the power equals the distance from the fulcrum to the weight and we find it required a little more power to raise the weight, so no advantage was gained except the change in direction.

2. Movable Pulley.

This form of pulley is a modified lever of the Second Class. The fulcrum is at one end of the rope touching the side of the pulley and the power at the other end of the rope at the other side of the pulley, the weight being between them. The power arm in a single movable pulley is twice the weight arm. There is a saving of power, but the power moves through a greater distance so there is a loss of time. To be of any great advantage the movable pulley must be used with a fixed pulley so that the direction of the pull can be changed. Where great weights are to be raised, pulleys with several grooves are used. The number of parts of the cord supporting the movable pulley, multiplied by the power equals the weight. ($W = P \times \text{number cords}$); as, If a weight of 12 pounds is supported by a pulley having 3 cords it can be balanced by a power of 4 pounds.

ILLUSTRATIONS.—Derrick, window sashes, elevators, rigging of ships.

EXPERIMENT—To show that a movable pulley having a continuous cord and a given power, will support a weight twice as great as itself.

Method—Fasten one end of string to a hook in the wall. Pass the string around the pulley and fasten the spring balance to the other end of the string so that the pulley divides the string into two parts. Attach the weight to the pulley. Raise the weight by raising the spring balance.

Result—The weight of eight pounds was balanced by a power of four pounds being two parts to the cord supporting the movable pulley and the power moves through twice as great a distance as the weight. $P. \times Pd. = W. \times Wd.$

WHEEL AND AXLE.

This consists of a wheel fastened in such a way to a cylinder that they turn together on the same axis. It is a modified lever of the First Class because the power is applied to the wheel, the axis is the fulcrum, and the weight is fastened to the axle.

ILLUSTRATIONS—The moving handle of a windlass describes a circle which forms the wheel; the cylinder on which the rope winds is the axis. In the capstan a spoke moving forms the wheel. In these ways the wheel and axle are used in cranes, dumb-waiters, belted and geared worm wheels.

Rule—Power times power distance equals weight times weight distance.

EXAMPLE—Draw two circles within one another, their centers coinciding, the inner representing the axle, the outer the wheel. Draw the horizontal radius of the larger circle and continue it to a point in the circumference of the small circle. The center is the fulcrum; the distance from the fulcrum to the end of the line in the large circle is the Power distance; from the fulcrum to the end of the line terminating in the circumference of the small circle is the weight distance. So that if the weight distance is 2 inches and the power distance 5 inches a weight of 125 pounds could be raised with a power of 50 pounds.

INCLINED PLANE.

This is a plane surface that makes an angle with a horizontal surface.

ILLUSTRATIONS—Rolling a barrel on a plank into a wagon; inclined railroads.

The *weight* is the thing to be moved; the *power* is the force moving the weight; the *power distance* is the length of the inclined plane; the *weight distance* is the vertical height of the plane.

Rule— $W. \times WD. = P. \times PD.$

EXPERIMENT—Attach one end of the string to a car weighing 6 pounds and the other to the spring balance. Raise one end of the one foot board or the inclined plane 6 inches from the horizontal. Keep the string parallel to the inclined plane, and pull the car up by the spring balance and record the result noted on the balance. Repeat experiment raising board to different heights.

Result—In each case $w. \times wd. = p. \times pd.$ As in first instance (w.) 6 lbs. $\times$ (wd.) 6 in. = (p.) 3 lbs. $\times$ (pd.) 12 in.; $36 = 36.$

WEDGE.

This is a triangular prism used to split bodies into two parts or to raise great weights a short distance. It is a movable inclined plane or two such planes placed base to base. The power is usually applied by repeated blows of a heavy body on the thick end of the wedge called the head. With a given thickness, the longer the wedge the greater is the mechanical advantage. Owing to the method of applying the power and the character of the work to be accomplished it is difficult to give a fixed law.

ILLUSTRATIONS—Splitting logs, stones, launching ships, using a hatchet, screw driver.

SCREW.

The Screw is a combination of a lever and an inclined plane. The inclined plane is wound around a cylinder, the elevations being called the threads of the screw and the distance between the threads the pitch.

EXAMPLE—Cut a triangular piece of paper and wind it around a pencil the hypotenuse of the paper forming the threads.

The *power* is usually applied at the end of a lever as the handle of a wrench, or by a wheel as in a letter press. The screw works in a nut which has threads inside. The nut may remain still and the screw move in it, or the nut move and the screw remain still.

Rule—The weight to be moved, is to the power employed; as the power distance or radius of the circle through which the lever or wheel moves, is to the weight or the distance between the threads. $W : P :: Pd : Wd. =$

ILLUSTRATION OF SCREWS—Jackscrows, cotton and hay presses, the vise, bench and clamp, and other uses in machinery and wood work, screw propeller in ships.

Friction is the resistance which a body meets with in moving in contact with another body.

SOME ADVANTAGES OBTAINED FROM MACHINERY.

1. Either a gain of intensity of force or a gain in speed is secured. These are known as mechanical advantages.
2. They permit us to use a force in a direction that is more convenient than the direction in which the resistance has to be moved.
3. They permit us to make use of other forces than our own muscles to do the work.

MECHANICS OF LIQUIDS (Water as a type).

Hydrostatics treats of liquids.

The particles of a liquid have the power of mobility, assuming the size and shape of the vessel in which they are placed, the top surface being level and always at right angles to the general direction of the sides.

EXPERIMENT—Pour water into one pan and ice into another and note the surface of each. *Result*—Ice remained in lumps forming an uneven surface. Water spread over bottom of pan and presented a level surface on top and took the shape of the pan.

1. LAW—PRESSURE.

Liquids exert pressure in all directions and the pressure increases with its depth.

EXPERIMENT—Place a finger at the end of a water faucet and turn on the water and we find a spray is sent out in all directions equal distances.

EXPERIMENT—Fill a clay pipe with water, tying rubber sheeting over the bowl of the pipe; connect the stem of the pipe and a glass tube by rubber tubing; pour colored water into a glass tube and tie the string marking its level. Lower the pipe into a jar of water and note the height of the surface of the water in the tube. Turn the bowl of the pipe in different directions, lowering it into the jar of water, and note the effect on the level of the water in the tube. *Result*—The liquid in the jar in each case, no matter in what direction the pipe was lowered, transmitted a pressure causing the level of water in the tube to be raised, and the deeper it was lowered into the jar the greater was the pressure exerted by the liquid.

Pressure of Deep Water—The layers of water near the bottom bear the pressure of the weight of all the layers of water above, so the further below the surface we go the greater will be the pressure, the pressure being proportional to the depth, hence layers two feet below the surface will be pressed upon with twice as much water as those only a foot below.

2. LAW—TRANSMISSION OF PRESSURE.

Pascal's Law—Pressure exerted anywhere upon an inclosed liquid is transmitted equally in all directions and acts at right angles to the surface.

EXPERIMENT (a)—Fill a thin glass bottle with water, insert a tight-fitting cork and press down on the cork. *Result*—The bottle is shattered, showing that the pressure was exerted in all directions.

EXPERIMENT (b)—Cover the bowl of a clay pipe with rubber sheeting and connect it with a glass funnel by rubber tubing, pour in a liquid and tie the sheeting over the mouth of the funnel. Press on the sheeting covering the funnel and turn the bowl of the pipe in different directions keeping the sheeting level.

Result—Each time we pressed on the funnel the pressure was transmitted by the liquid to the sheeting covering the pipe causing it to bulge out. This was true no matter in what direction it was held.

WATER AS A MECHANICAL POWER.

HYDROSTATIC PARADOX.

An application of *Pascal's Law* is made in the *Hydraulic Press* and is so strange as to be known as the *Hydrostatic Paradox*, for the pressure depends only on the depth of the liquid, not on the quantity or size of the vessel.

EXPERIMENT—Insert corks and connect two cylinders, one having an area across the top of 1 square inch, and the other 10 square inches. Then apply a pressure of 1 pound on the cork of the small cylinder. *Result*—The pressure being transmitted equally in all directions each square inch of cork in the large cylinder received an upward pressure of a pound so that had a weight been placed on the larger cylinder, ten pounds could have been raised by the one pound pressure on the small cylinder.

Use—The hydraulic press is used for applying enormous pressure to paper, cotton, hay, and for extracting oil from seeds, making holes in iron plates, etc.

HYDRAULIC PRESS.

The upward movement of the piston is very slow but this slowness is hardly considered a disadvantage when we take into consideration that one man working the press can do work which it would take a hundred or more men to do.

LEVEL OF LIQUIDS.

Liquids seek their own level. That is water at rest in several communicating vessels will all remain with their surface on a horizontal line, or level, for no matter what the size or shape of the vessel from the last law and experiment we know the upward pressure to be the same.

EXPERIMENT (a)—Pour water into a kettle and note that the level of the water in the spout and the kettle is the same.

EXPERIMENT (b)—Connect two glass tubes with rubber tubing and pour a liquid into one and note to what height the liquid rises in the other tube. Raise and lower one tube and note the height of the liquid in the other one.

Result—The liquid stood at the same level in both tubes every time after they had come to rest.

WATER SUPPLY.

The reservoir supplying the city with water is placed as high as possible so that water will run into the highest buildings without a pump. The water seeking its level will go as high as the source of the supply. By means of stop cocks and faucets the water is prevented from overflowing on the lower floors.

Brooklyn Water Supply.

1. Fresh water lakes and streams on the southern slope of Long Island west of Amityville. Artesian wells in the same district, directed by pumping stations to reservoirs at Ridgewood and Prospect Park.
2. Outlying districts are supplied by their own artesian wells.
 - a. Flatbush (Paerdegat Creek).
 - b. New Utrecht (E. 14th St. and Ave. V).
 - c. Gravesend (E. 17th St. and Ave. K).
 - d. New Lots (Fresh Creek).

SPRINGS.

A *spring* is a well formed by nature. Some of the rain which falls trickles through the sand and soil until it reaches a layer of slate or rock through which it cannot pass. It follows the slant of the rock until it reaches the lowest point and there collects and forms an underground spring.

AN ARTESIAN WELL.

This is a well which receives its name from the place Artois in France where it was first used. A hole is bored in the ground until the spring is reached and then a pipe is sunk. The water will rise in it until it reaches the level of the highest point of the source of supply. This is often many feet.

A FOUNTAIN.

This is formed whenever the pipe containing the liquids is not long enough to reach to the height to which the water is being forced.

EXPERIMENT—Two tubes containing water are connected by a rubber tube. When the one is raised above the other a fountain is formed at the top of the lower one. The higher column of water, producing more pressure than the lower one, forced the water out.

WATER WHEELS.

Since olden times water wheels have been used to obtain power from water on the principle that streams flow toward a lower surface because of the tendency of liquids to seek their own level.

1. An Overshot Wheel.

This is one whose circumference is filled with paddles and is turned by water flowing over the top of the wheel, the weight of the water as it falls on each paddle causing the wheel to turn.

2. The Undershot Wheel.

This is similar to an *overshot wheel* except that the water flows beneath the wheel striking the paddle forcing them out and so turning the wheel.

3. A Breast Wheel.

This wheel is moved by water striking the wheel midway so that both the weight of the water and the force of the current are made use of in turning the wheel.

4. Turbine Wheel.

This is a horizontal wheel having a series of curved paddles against which the water strikes. The wheel is enclosed in a case usually at the bottom of an upright pipe carrying down the water, thus producing great water pressure.

The weight of the water in this tube increases the velocity with which the water strikes the paddles. The water enters the openings in the case so arranged as to throw the water against the blades of the wheel most effectively. After leaving the paddles the dead water escapes from the central part of the wheel, sometimes by a vertical draught tube. A central shaft is carried by the wheel and is connected with the machinery above. The case protects the wheel from the vertical pressure of water.

BUOYANCY.

This is the tendency of a liquid to lift up and support a submerged body. The amount of buoyant force depends on the density of the liquid and the size of the submerged body.

FLOTATION.

Laws of Immersed and Floating Bodies known as **Archimedes Principles**.
(Archimedes of Sicily discovered the Laws of Flotation).

1. Bodies immersed in a liquid displace their own volume.
2. When anything is weighed in water it will lose weight exactly equal to the weight of the liquid it displaced.
3. Bodies that are lighter than the water they displace will float; as, cork, wood.
4. Bodies that are heavier than the water they displace will sink; as, stone.

ILLUSTRATIONS—Floating of ships, ballast, etc.

EXPERIMENT—Illustrating Archimedes principle.

Having weighed a pan, place in it a jar and fill it with water. Attach a weight to a spring balance and lower the weight into the water. Note its weight before and after lowering it into the water. Weigh the pan and water which overflowed from the jar. Compare weight of the object and the weight of the displaced water.

Result—The pan weighed 5 ounces. The body weighed in air 24 ounces, when lowered into the water it weighed 20 ounces having lost 4 ounces. The pan and displaced water weighed 9 ounces, showing the weight of the displaced water to be 4 ounces, the same as the weight lost by the body upon being immersed in the liquid.

SPECIFIC GRAVITY.

This means the number of times heavier a body is in air than an equal volume of water.

The Specific Gravity of Bodies Heavier than Water is found by dividing the weight in air by the weight of the water displaced or the difference between the weight in the air and the weight in the water.

Specific Gravity equals the weight in the air divided by the weight of the water displaced.

As, Iron weighs 14 pounds in air.

Iron weighs 12 pounds in water.

Water displaced weighs 2 pounds.

Weight in air, 14 pounds divided by the weight of the water displaced 2 pounds equals 7, the specific gravity.

Specific Gravity of Bodies Lighter than Water is found by attaching a sinker to the body so that it may be immersed.

Weigh the body in air.

Weigh the sinker in air.

Weigh the sinker in water.

Find the loss of weight by both the body and the sinker in water; from the loss of these two subtract the loss of the sinker and the difference will be the loss of the body. Divide this into the weight in air and the answer will be the specific gravity.

SPECIFIC GRAVITY OF SALT WATER.

Salt Water weighs $2\frac{3}{4}$ lbs.

Water weighs $2\frac{1}{4}$ lbs.

$2\frac{3}{4} \div 2\frac{1}{4} = 1\frac{1}{2}$, Specific Gravity of Salt Water.

SPECIFIC GRAVITY OF KEROSENE.

Weight of Kerosene, $1\frac{3}{4}$ lbs.

Weight of Water, $2\frac{1}{4}$ lbs.

$1\frac{3}{4} \div 2\frac{1}{4} = \frac{7}{8}$, Specific Gravity of Kerosene.

The Hydrometer is an instrument used in testing the density of acids, milk, alcohol, etc.

MECHANICS OF GASES (Air as a type).

Pneumatics treats of the mechanical properties of gases.

Properties of Gases.**1. Expansibility.**

EXPERIMENT—Place a toy balloon with a little air blown into it under a receiver of an air pump. As the air is exhausted the balloon stretches out showing that the air within is expanding the balloon.

2. Compressibility.

EXPERIMENT—Force down a piston in a cylinder closed at the bottom and the air will be compressed.

3. Elasticity, a tendency to fill any vacant space.

EXPERIMENT—Allow the piston to remain at the bottom and it will begin to rise, showing the elasticity of the air below.

4. Weight.

EXPERIMENT—Weigh a vessel containing air, place it under the receiver and exhaust the air and then weigh it and it will be found to be lighter than at first.

5. Exerting Great Pressure at the Surface of the Earth.

EXPERIMENT—Close a long narrow glass tube at one end, then fill it with water. Invert the tube and hold it up, the water remains in the tube showing that there must be an upward pressure of air. Open the top of the tube and the water runs out showing that there was a downward pressure of air and that its weight plus the weight of the water was sufficient to overcome the upward pressure of the air.

ATMOSPHERIC PRESSURE.

Fill with mercury a stout glass tube 33 inches long, closed at one end. Invert it in a bowl of mercury. Note how far the mercury falls. In spite of the tendency of liquids to seek their level we see that some force equal to the weight of the column of mercury is supporting the mercury in the tube. A tube of mercury 30 inches high and 1 square inch weighs 15 pounds therefore a column of air 1 square inch and the height of the atmosphere above the earth at the level of the sea must weigh 15 pounds in order to balance the column of mercury.

BAROMETER.

It was invented by Torricelli. He filled a tube with mercury inverted the tube and placed the open end in a bowl of mercury. The mercury in the tube then fell

until its height was 30 inches. It stood at this height because the air at the sea level is heavy enough to hold up a column of mercury 30 inches. A scale is attached to the tube which is read in degrees.

Uses.

1. The Barometer is used to determine the **Weight of Air** and shows all **Changes of Atmospheric Pressure**.

- a. The falling of mercury generally denotes foul weather.
- b. A sudden fall of the mercury denotes storm.
- c. An unchanging high barometer denotes settled fair weather.
- d. A rising barometer denotes fair weather.

2. To Find the Height of Mountains.

The atmosphere becomes less dense as we ascend from the surface of the earth. If a barometer is carried up a mountain the mercury falls constantly as the elevation increases, about 1 inch for every 1,000 feet of ascent.

If water had been used in the barometer instead of mercury it would have had to be 34 feet long, for the specific gravity of mercury is 13.6, hence 13.6 times 30 equals 408.12 or 34 feet.

SIPHON.

This is a bent tube with arms of unequal length, which is used to transfer a liquid from one vessel to another at a lower level by carrying it over the edge of the vessel. It is useful for removing liquids from tanks, casks and barrels which cannot be overturned, and removing liquids when the lower layers are not to be disturbed; as, drawing the clear liquid from the sediment.

ACTION—The siphon is set in action by filling the tube with water to force out the air. The short end is placed in the vessel to be emptied and the liquid flows until the end of the tube gets above the water or until the liquid stands at the same level in each vessel. The height of the short arm cannot be more than 34 feet, if higher a vacuum will form there, for atmospheric pressure is unable to raise water to a greater height than 34 feet.

There is a pressure of one atmosphere on the surface of each vessel minus the weight of the water in each arm of the tube and as the water in the long tube weighs more than in the short one there is more upper pressure at the end of the short tube than at the end of the long one; hence the flow of water.

ILLUSTRATION—Intermittent springs are natural siphons.

SUCTION OR LIFTING PUMP.

Principle—Atmospheric pressure—Air can support a column of water 34 feet high.

DESCRIPTION—This pump consists of a cylinder, a piston, two valves and a pipe about twenty-seven to thirty feet long. The lower end of the pipe dips into the

liquid to be raised. The piston has a valve opening upward and there is a valve opening upward at the top of the pipe.

ACTION—When the piston is drawn upward its valves are closed by the pressure of the air above. When the piston is pushed down the valve in the piston opens and some of the air from the cylinder escapes. As the piston continues its work the air is taken from the cylinder and the atmosphere presses the water out of the spout.

This form of pump has been in use since the fourth century B. C.

FORCE PUMP.

This is a device to deliver water at a point higher than the place at which it is convenient to put the pump.

This pump has no valve in the piston, so that when the water is raised in the cylinder of the pump it is forced through an opening to an air chamber and then forced through a pipe to any height.

ILLUSTRATION—Double acting steam fire engines, and hydraulic presses.

EXHAUSTING AIR PUMP.

This is an instrument used for removing air from vessels connected with the pump. It is constructed similar to a lift pump having two valves, one in the piston and one in between the cylinder and the pipe, the valves opening outward. Such a pump must be very strong so that there will be no leaking of air.

This pump was invented by Guericke of Germany in 1650.

Use.

1. Air is partially exhausted from vacuum pans in making sugar so that evaporation will take place at a lower temperature and the sugar not burn.
2. Incandescent lamps.

CONDENSING AIR PUMPS.

This is used for putting air into anything. It is similar to the exhausting pump, the difference being that the valves open in the opposite direction.

ILLUSTRATION—Bicycle pump; transferring gas from one cylinder to another for a limelight.

BALLOONS.

Principle—If a body immersed in air is lighter than the air it displaces, it will float.

DESCRIPTION—A large silk or cotton bag is covered with varnish to make it air tight, and then filled with hydrogen, common illuminating gas, or with some gas enough lighter than air so that the whole weighs less than a body of air of the same size. Ordinarily it is not completely filled with gas at the start for as it ascends the outside pressure diminishes so that the bag would be liable to burst before reaching any considerable altitude if filled full at the start. At the top of the bag is a valve through which the gas may be allowed to escape so that the balloon may descend. A network of ropes covers the bag and supports a car or basket hanging below. Sand bags are always carried to be thrown overboard if it is desired to lighten the balloon. An anchor is tied to a long rope to be used in descending.

USES OF COMPRESSED AIR.

1. **Toy Air Gun and Bean Blower**, the compressed air in back of the projectile drives it out.
2. **Pneumatic Tube** used in stores for carrying parcels and money. The air is removed in front of the tube and the air forced into the tube at the other end. The compressed air drives the carriage with great force.
3. **Pneumatic Drill**. A device for using compressed air to drive the drill. It enters one side and is forced out through the other, thus turning the drill.
4. **Pneumatic Hammer**. A device for using compressed air to deliver heavy blows. The hammer is fastened to a piston. The stroke is regulated by the amount of compressed air admitted to either side of the piston.
5. **Diving Bell**. This is a heavy hollow bell-shaped body in which men may descend and work under water, breathing being sustained by compressed air at the top or by fresh air being pumped in through a tube from above.

Use—A device for putting in the foundation of bridge piers, and doing underground excavating.

Caisson is an immense stationary diving bell entered by workmen through air tight doors. It is used in bridge building.
6. **Atomizer**.
7. **Pneumatic Tire**. Ordinary bicycle tire.
8. **Bellows**.
9. **Air Brake**. The piston drives the brake shoes against the wheel by compressed air. When it is desired to remove the brake the compressed air is allowed to escape and this frees the wheels.

QUESTIONS.

What is matter?

What are the three states of matter?

How does a liquid differ from a gas?

What is meant by capillarity? Give an illustration of capillary attraction.

What is inertia?

When a street car suddenly stops what happens to the passengers? Why?

In what kind of equilibrium is a board floating on its broad side? When raised on its edge?

Why does a man lean forward in climbing a hill?

Why is an inkstand usually large at the base?

Why does a person carrying a heavy load in one hand throw out the opposite hand?

Which is more stable, a load of hay or a load of stone, each weighing 2 tons? Why?

Give reasons why a pyramid is a stable body.

How would you arrange a crowbar to use it as a lever of the first class?

Draw a lever of the first class in which the power arm and the weight arm are each 5.

How much can a person who weighs 87 pounds lift with a lever of the first class 5 feet long, the fulcrum being 1 foot from the weight?

A lever 9 feet long weighs 8 pounds. Where must a force of 100 pounds be applied to balance a weight of 800 pounds at one end, 2 feet from the fulcrum?

Which class of lever is represented by a pair of shears, a wheelbarrow, an oar in a boat, a claw hammer, tongs, scales, pair of scissors, lemon squeezer.

A lever is 6 feet long. Where must the fulcrum be placed so that a weight of 600 pounds at one end will balance 100 pounds on the other end?

A crowbar 3 feet long has a stone for a fulcrum 6 inches from the end. If a man presses with a force of 75 pounds, what weight can he move.

In what class of levers is the weight distance a part of the power distance?

In what class of levers is the power distance a part of the weight distance?

What weight can be raised by a lever of first class with a power of 125 pounds, the Wd. being 4 inches and the Pd. 2 feet?

What weight can be raised by a lever of the second class when the Wd. is 18 inches and the Pd. $6\frac{1}{2}$ feet and the power 450 pounds?

State general law of levers.

Name three important points of a lever.

Name three applications of an inclined plane.

What power must a man use to roll a barrel weighing 300 pounds up a plank 7 feet long into a wagon 4 feet high?

A barrel on a plank 12 feet long being rolled into a door 4 feet above the ground weighs 300 pounds. With what force must a man push in order to prevent it from rolling back?

A man rolls a barrel weighing 800 pounds into a wagon 3 feet high. He can lift 150 pounds. How long a plank must he use for an inclined plane.

A windlass has an axle 1 foot in diameter and a handle 3 feet long. What power must be used to raise 1,000 pounds?

What is the amplitude of a pendulum's vibration?

If a clock gains time what may be done to the pendulum to remedy this?

In what direction is pressure by liquids when at rest?

What is meant by specific gravity?

Why is a body easier moved under water than above?

Explain the working of a hydraulic press.

As iron is heavier than water why does not an iron ship sink?

Prove that air exerts a downward pressure.

If butter costs 35 cents a pound how many kilograms can be bought for \$3.08?

If a building is 525 metres high how many feet is it?

A tank 10 by 6 by 12.5 centimeters will hold what weight of water?

How much force must be exerted to pull a sleigh weighing 100 pounds up a hill which rises 1 foot for every 6 feet of the hill?

Give the laws of gravitation.

A body moves at the rate of half a mile in 90 seconds. How long will it take to go 200 yards at the same speed.

If a boat 30 feet by 15 feet sinks 3 inches when loaded, what is the weight of the freight?

Is the water line of a boat the same in fresh water as in salt water?

Why is ballast placed in a ship?

Why does blotting paper absorb ink better than ordinary paper?

If a boat moves at the rate of 3 miles across a river which is 4 miles wide, with a current going 2 miles an hour, how long will it take to cross if no attention is paid to the current and where will the boat land?

(Draw diagram showing the resultant.)

Which is apt to be the most serious fall, one from a rapidly moving vehicle or a fall from a slowly moving one?

Will a balloon weigh more or less when it has risen 2 miles in the air than when starting at sea level?

What is the force which causes a water wheel to turn?

Why is it necessary to wind up a clock?

Which is heavier, salt or fresh, water? Why?

If a small tube be placed in a glass of water the water will rise higher in the tube than in the glass. Why?

Tuberoses will scent a whole room. To what property of matter is this due?

Can salt be obtained from salt water? If so, how?

- How do air and water differ? How resemble each other?
- Why do the drawers of a desk or dresser sometimes stick in warm, damp weather?
- How is dirty water made clear?
- Why is it harder to hammer a nail into hard wood than soft?
- In a movable pulley at rest how does the weight compare with the power?
- Into how many parts does a movable pulley divide its rope? What weight is supported by each part of the rope?
- Explain the working of a fountain.
- Of what use is a siphon? Explain its action.
- How high must the water tower or reservoir of a city be placed?
- Why does the water flow from the faucets of a house?
- How does water get into the reservoir?
- Explain what buoyancy is due to.
- Why is it easier to lift a heavy weight under water than in air?
- Which is heavier, kerosene or water?
- Why does a piece of small solid iron sink and a large iron-clad vessel float?
- What is a hydrometer used for?
- Why is a pail full of water so much heavier when raised above the water in the well than when nearer the bottom of the well?
- Is there any difference in the height of the mercury in a barometer when placed on the summit of a mountain? Why?
- Indicate how the barometer shows changes in the weather.
- Explain the movements of the valves in the different pumps.
- Explain the action of a force pump. When is such a pump used?
- Describe a suction pump.
- Is a pump ever used for air instead of water?
- What kind of a pump is a bicycle pump? A fire engine?
- In a siphon does the water run toward the short arm or the long one?
- What causes the water to flow in a siphon?
- Why is it sometimes necessary to remove the cover of a vessel to make the fluid flow more readily from the spout?
- Show how a barometer determines atmospheric pressure.

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